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ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Crown Competition Factor (CCF) for Engelmann Spruce in the Central Rocky Mountains

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The relationship between crown width and stem diameter at breast height for open-grown trees is presented for Engelmann spruce in the central Rocky Mountains. Maximum Crown Area (MCA) in square feet can be estimated from diameter in inches. The relationship of MCA to diameter is the basis for computing Crown Competition Factor (CCF), a measure of stand density.

Crown Competition Factor (CCF) is a measure of stand density developed by Krajicek et al (1961). CCF compares space occupied by a tree with that represented by the vertical projection of the average crown area of an open-grown tree of the same diameter. The percentage of an acre occupied by the vertical projection of the crown—obtained by dividing the area in square feet by 435.6—is the Maximum Crown Area (MCA). Because space occupied by a single tree is not easily determined, the comparison is made on a stand basis. CCF is the sum of the MCA values of all trees in the stand divided by the area in acres. Although it pertains to crowns and is expressed in percent, CCF is not a measure of crown closure, but a measure of the growing space available to the average tree in the stand in relation to the maximum area it could use if it were open-grown (Krajicek et al. 1961, Vezina 1962).

CCF has proved useful in comparing different measures of stand density, and establishing relationships between growth and density. Species tested include: upland oaks (Quercus alba L., Q. rubra L., and Q. velutina Lam.), shagbark hickory (Carya ovata (Mill.) K. Kock), and Norway spruce (Picea abies (L.) Karst.) (Krajicek et al. 1961); white spruce (P. glauca (Moench) Voss.), balsam fir (Abies balsamea (L.) Mill.), and jack pine (Pinus banksiana Lamb.) (Vezina 1962, 1963); and lodgepole pine (P. contorta Dougl.) (Alexander et al. 1967).

Methods

To establish the relationship between crown spread and stem diameter at breast height for open-grown trees—a necessary prerequisite to developing a CCF equation—116 free-growing Engelmann spruces (Picea engelmanni Parry) were measured

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in Colorado. Only those trees that met the following specifications (Krajicek et al. 1961) were included in the sample:

1. Crown free of competition on all sides.
2. Live branches extending to the ground or nearly so.
3. Lowest branches longest or at least as long as those above, indicating no release from past competition.
4. No evidence of forking, or storm, disease, or insect damage.

Sample trees were generally found in meadows, open parks, and old burns. No trees were selected below 9,000 feet elevation because observations indicated that free-growing trees in city parks, cemeteries, and along roads below the natural elevational range of spruce had wider crown spreads.

Crown width of each sample tree was the average of two measurements of maximum green width, made at right angles to each other with a tape. Diameters were measured at breast height with a diameter tape.

Relation of Crown Width to Diameter

The linear regression of average crown width (CW) in feet on diameter breast height (D) in inches is:

$$CW = 4.344 + 1.029D$$
$$r = 0.99 \qquad (1)$$
$$s_{\bar{y}} = 1.321 \text{ feet}$$

The relationship of crown width to tree diameter (fig. 1) applies specifically to open-grown Engelmann spruces in Colorado and southern Wyoming, and only to trees with diameters at breast height not larger than 30 inches. A few larger trees were sampled, but were not included in the analysis because a scatter diagram indicated that the rate

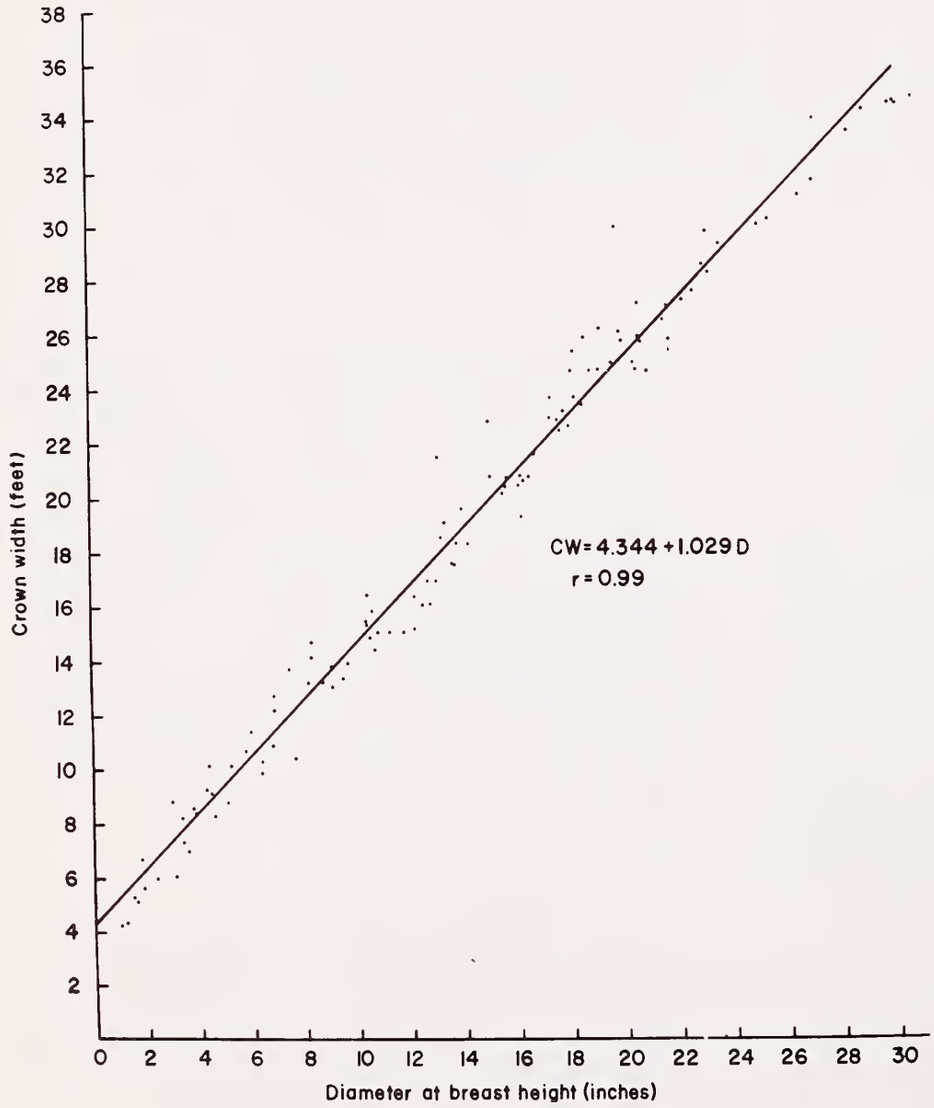

Figure 1.-- Relationship of crown width to stem diameter at breast height for open-grown Engelmann spruce.

of change in CW with D was slower for trees larger than 30 inches d.b.h.

The CW-D relationship for open-grown spruces is significantly different from that established for lodgepole pines (CW = 3.27 + 1.423D), a common associate in the central Rocky Mountains (Alexander et al. 1967). Open-grown spruces have much narrower crowns than lodgepole pines at any given diameter up to 30 inches d.b.h.

CCF for Engelmann Spruce

The maximum percentage of an acre that can be occupied by the crown of an Engelmann spruce of specified bole diameter is:

$$MCA = \frac{\pi (CW)^2 \times 100}{4 \times 43{,}560} = 0.0018 (CW)^2$$

From equation 1

$$CW^2 = 18.8729 + 8.9406D + 1.0588D^2$$

Therefore,

$$MCA = 0.0340 + 0.0161D + 0.0019D^2 \quad (2)$$

CCF for a spruce stand can now be estimated from a stand table by either (a) summing the MCA values for each diameter class and dividing by the area in acres, or (b) accumulating the MCA values of the trees in the stand in the following form:

$$CCF = \frac{1}{A}\left[0.0340 \sum_{i=1}^{k} N_i + 0.0161 \sum_{i=1}^{k} D_i N_i + 0.0019 \sum_{i=1}^{k} D_i^2 N_i\right] \quad (3)$$

D_i = ith d.b.h. class
N_i = number of trees in ith d.b.h. class
A = area in acres
k = number of d.b.h. classes in stand

An example of the computation of CCF for an Engelmann spruce stand by both (a) and (b) is given in table 1.

Table 1.--Determination of the CCF in an Engelmann spruce stand. Plot size 0.4 acre

D (d.b.h.)	N_i	DN	D^2N	MCA per tree	Total MCA
4	27	108	432	0.129	3.483
5	25	125	625	.162	4.050
6	18	108	648	.199	3.582
7	14	98	686	.240	3.360
8	11	88	704	.285	3.135
9	2	18	162	.334	0.688
10	3	30	300	.386	1.158
11	4	44	484	.442	1.786
12	6	72	864	.502	3.012
13	7	91	1,183	.566	3.962
14	3	42	588	.634	1.902
15	5	75	1,125	.705	3.525
16	4	64	1,024	.780	3.120
17	2	34	578	.860	1.720
18	2	36	648	.942	1.884
19	3	57	1,083	1.029	3.087
Total	136	1,090	11,134		43.416

$$CCF = \frac{\text{Total MCA}}{\text{Area in acres}}$$

$$CCF = \frac{43.416}{0.4}$$

$$CCF = 108.54$$

$$CCF = \frac{1}{A}\left[0.0340 (136) + 0.0161 (1090) + 0.0019 (11134)\right]$$

$$CCF = \frac{43.328}{0.4}$$

$$CCF = 108.32$$

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